COVER SHEET

BUILDING CONTRACT PRICE FORECASTING: PRICE INTENSITY THEORY

Dr John Gunner
Montville
Queensland
Australia

Prof Martin Skitmore
School of Construction Management and Property
Queensland University of Technology
Gardens Point
Brisbane 4001
Queensland
Australia

10 December 1997 (version 1)

BUILDING CONTRACT PRICE FORECASTING: PRICE INTENSITY THEORY

ABSTRACT: A theory of contract price forecasting bias is proposed based on the heuristic bias framework and with reference to the common practice of basing building price forecasts on the price per square metre of floor area or Price Intensity (PI). The main prediction of the theory, that high PI contracts will be underestimated and low PI contracts will be overestimated, is tested by a reanalysis of Singapore data and in comparison with previous work. It is concluded that PI theory may be necessary and sufficient to explain all systematic biases in contract price forecasts.

Keywords: Price Intensity Theory, judgement bias, building contracts, price forecasts.

INTRODUCTION

Despite a wealth of empirical studies aimed at identifying underlying causes of estimating bias (*eg.* Cheong, 1991; Flanagan and Norman, 1983; Gunner and Betts, 1990; Jupp, 1981; Lau, 1991; Morrison, 1984; Ogunlana, 1989; Skitmore, 1985, 1988; Skitmore *et al*, 1990; Thng, 1989), scant attention has been paid to the development of explanatory theories of building contract price forecasting (Skitmore, 1988; Skitmore *et al*, 1990).

One of the most common findings of the empirical work to date has been the seeming identification of correlation between forecasting bias and the size of project, with the degree of bias reducing with increased project size in both absolute and percentage terms (*eg.* Flanagan and Norman, 1983; Morrison, 1984; Morrison and Stevens, 1980; Harvey, 1979; Gunner, 1997). However, several other variables (see Gunner, 1997) have also been found to be correlated with bias, in addition to project size. Whilst an interesting 'fact', this can hardly be said to constitute an entire theory. In fact, it has no theoretical status at all. It is simply a phenomenon without an explanation.

To address this problem, we start our analysis from a different point altogether, by reference to the judgement bias literature, from which a completely new theory is derived based on Price Intensity. Following the Popperian philosophy, an attempt is then made to refute the PI theory in favour of the project size 'phenomenon', and other likely variables, through a reanalysis of Gunner's (1997) Singapore data. Under the somewhat restrictive conditions of the analysis used (linear regression) the refutation does not succeed. Further attempts at refutation of the theory are also described through a rexamination of previous work. These attempted refutations also fail. As a result, it is concluded that PI theory is a tenable explanation of such systematic forecasting bias that exists to date.

PRICE INTENSITY THEORY

Judgement biases

Forecasting, by definition, is concerned with predicting future events. It can be viewed as a choice amongst a range of discrete possibilities. In building price forecasting, forecasters are faced with a choice of prices to apply to the various components of the forecast. This is so whether in the early stages of design, where the choice is the rate to apply at a broad brush level (eg. the functional cost per bed for a hotel), or in the later stages of design, when more detailed estimates can be made, such as the price per unit area of a brick wall. Most often, forecasts are based on the price per unit of floor area (Fortune and Lees, 1996) and are continually refined as the design evolves. This unit price, commonly expressed in dollars per square metre, is termed here Price Intensity (PI). By this definition, contracts with a relatively high PI can be said to be relatively 'expensive' contracts and those with a relatively low PI are therefore relatively 'cheap' contracts.

Forecasting is also an uncertain business, the events to be predicted being at best being known only in probabilistic terms. Building price forecasting is highly subjective and therefore involves considerable judgement on the part of the forecaster. Judgement is necessary in taking an appropriate ‘cue’ or rate (a base price) and adjusting it to meet the particular requirements of the building being designed. Such adjustments also include, but are not limited to, allowances for price inflation, currency movements on imported materials and the effect of different locations. Inevitably forecasters make errors in their judgements of the relevant price and the introduction of bias, in the form of systematic errors, is a common occurrence. Positively biased forecasts overestimate the actual prices and negatively biased forecasts underestimate the actual prices. Building price forecasts are known to be universally positively biased (Gunner, 1997).

Some possible causes of bias when exercising judgement in the property/construction domain have been suggested by Raftery (1996). These relate to work in the field of judgement biases. Tversky and Kahneman (1982) identified "a number of heuristic principles that reduce the complex tasks of assessing probabilities and predicting values to simpler judgemental operations". They found that the heuristics "are quite useful, but sometimes lead to severe and systematic errors". As noted by Raftery (1996), three of these heuristics are employed to predict values, which makes them leading candidates for explaining biases in building price forecasts. These are the representativeness, availability, and adjustment and anchoring heuristics, a brief account of which follows.

Representativeness

Many of the questions that people face when making predictions revolve around decisions such as: What is the probability that object A belongs to class B? If object A is highly representative of class B to a high degree then people will judge that object A belongs to class B. "This approach to the judgement of probability leads to serious errors, because similarity, or representativeness, is not influenced by several factors that should affect judgements of probability" (Tversky and Kahneman, 1982).

Base rate frequency is the prior probability of occurrence which should have a major effect on the outcome and is nothing to do with representativeness. Similarly, the weight to be applied to differing sample sizes clearly leads to the view that more reliance should be placed on larger, rather than smaller, sample sizes. Surprisingly, however, "this fundamental notion of statistics is evidently not part of people's repertoire on intuitions" (Tversky and Kahneman, 1982:6), the available evidence generally being underutilised - a phenomenon termed '*conservatism*'.

Misconceptions of chance occur when people expect that a sequence of events generated by a random process will represent the essential characteristics of that process even when the sequence is short, and therefore possibly unrepresentative.

Insensitivity to predicability happens when people are called upon to make predictions of future value and then discount the fact that an inherently wide range of price makes certain prediction impossible.

The illusion of validity is the unwarranted confidence placed on predictions based upon high degrees of representativeness. "This illusion persists even when the [forecaster] is aware of the factors that limit the accuracy of his predictions" (Tversky and Kahneman, 1982:9).

Misconceptions of regression concern the lack of understanding that people have towards the occurrence of chance events about a mean. "People do not develop correct intuitions about this phenomenon. First, they do not expect regression in many contexts where it is bound to occur. Second, where they recognise the occurrence of regression, they often invent spurious causal explanations for it" (Tversky and Kahneman, 1982:9).

Availability

Availability is "a useful clue for assessing frequency or probability, because instances of large classes are usually reached better and faster than instances of less frequent classes. However availability is affected by factors other than frequency and probability. Consequently, the reliance on availability leads to predictable biases" (Tversky and Kahneman, 1982:11). This has been confirmed in a number of experiments which illustrate that, to the extent that our environment differentially emphasises certain types of events, judgement is biased by the ease with which such instances are recalled and therefore in how their frequency is forecasted.

Adjustment and Anchoring

A judgemental strategy that is highly dependent on information presented or available to a person as 'anchoring and adjustment' (Tversky and Kahneman, 1982:14). It has been shown repeatedly that, once an initial figure is imprinted (anchored) in a person's mind, any adjustments made to that figure in the light of new information tend to be underestimated. "There is reason to believe that many intuitive anticipations are based on anchoring and adjustment strategies ... Anchoring and adjustment seems to be judgemental strategy that is almost as necessary as availability. That is predictions are made by reference to cues that are available, adjustments are

then made concerning the particular case to be predicted relative to the available cues. Furthermore, availability and anchoring and adjustment are strategies that both depend heavily upon the initial point in the judgemental process: the information available and which forms the anchor" (Hogarth, 1987:54).

Price Forecasting within the Heuristic Bias Framework

Likely examples abound in the context of price forecasting. It is normal practice for a forecaster to select one or two similar previous past contracts for which prices are known (Beeston 1974, Skitmore, 1985) and with preference for contracts on which the forecaster has been personally involved (Skitmore, 1985; Skitmore *et al*, 1990). As Beeston has pointed out, bias could arise from this practice through misconceptions of chance in the selection of samples of inadequate size and the over-interpretation of findings based thereon. Price forecasters may have unfounded confidence when asserting that they are confident of accurately predicting costs for a particular type of building, even though they are aware of the wide range of likely prices which represent the variances in that building type. The price forecast for a particular building function may be heavily influenced by the number of similar projects for which the price forecaster has predicted values in the recent past. In addition, forecasting the price for meeting the requirements of a building performance specification for a highly technical, and singular, contract is a possible example of where insensitivity to predicability may occur.

What is known of the process of forecasting a future price for a building then suggests the heuristic bias framework to be appropriate. This implies that, because of 'conservatism' and regression, the price forecaster is likely to select a price which represents the middle, or average, of the range of possible values for an initial anchor but, due to the anchor effect, make insufficient adjustments towards to what will eventually be the actual contract price. As suggested by Skitmore (1985) and Skitmore *et al* (1990) experimental work in early stage estimating and supported by Fortune and Lees' (1996) survey of common practice, forecasters take the price per square metre floor area, or Price Intensity (PI), of a comparable building as the starting point (anchor) cue for forecasting the price of a new building and then make adjustments to that value according to anticipated differences between the cue and the new building. According to the heuristic bias framework, such adjustments are likely to be sufficient, leading to a tendency to under forecast expensive buildings and over forecast less expensive ones.

The crucial aspect of this argument is that the underadjustment will be in terms of PI. That it is accountable **only** in these terms is a theoretical proposition of some magnitude, but certainly amenable to empirical examination. More formally, **PI theory holds that Price Intensity alone is both necessary and sufficient to account for systematic bias in building contract price forecasting**. Furthermore, if correct, PI theory should also apply equally at any stage of the design development process when building price forecasts are made, from early stage forecasts to those at the pre-bid stage.

REANALYSIS OF SINGAPORE DATA: MODELLING UNDERLYING FACTORS

Full details of the Singapore data, its analysis and comparison with previous empirical studies are described in Gunner (1997). In that study, a series of bivariate analyses for bias and consistency

successfully modelled a number of independent variables affecting price forecasting performance. Some independent variables were shown to affect bias and consistency. The result of this work was to show that not only was this and previous analyses of similar data compatible and homogenous, but that a single underlying variable may exist - its identification being clouded by confounding effects of other variables in the analyses.

PI theory predicts that Price Intensity is the one variable that is necessary and sufficient to account for any systematic bias involved. To test this theory rigorously, according to Popper, involves trying to refute the theory. This known to be a very stringent test that, in principle, involves an exhaustive search among all other possible competing variables for a combination that performs better than Price Intensity. Rather less stringent, but one that subscribes to the principle embodied in *Occam's Razor*, is to test for a single underlying variable. The existence of the project size phenomenon, referred to in the introduction to this paper, as a major rival to PI theory suggests the starting point for this to be a comparison between the two.

To do this, a multiple regression model was built from the Singapore data and in which variables representing both project size and Price Intensity were entered initially. This was subsequently followed by further regression analyses in which a variety of variables were entered to test for the existence of an underlying variable. PI theory predicts this underlying variable to be Price Intensity and will therefore be disconfirmed if either no underlying variable emerges or, if an underlying variable does emerge, it is not Price Intensity.

This analysis is described below.

Model

The approach adopted to test the PI theory was to work with the model: (1)

Where y = dependent variable u = a possible underlying factor v = an independent variable.

If the hypothesis that there no other variable of significance is not to be refuted, the regression coefficient for Price Intensity should always be significant whereas all other variable coefficients should never be significant.

Selection of Variables

As already mentioned, project size has been frequently expressed to be significant in affecting in the accuracy of price forecasts. This has been represented by the contract sum (*eg.* Harvey, 1979; Flanagan, 1980; Flanagan and Norman, 1983; Wilson *et al*, 1987; Skitmore, 1988); contract period (Flanagan, 1980; Morrison and Stevens, 1980; Skitmore, 1988; Ogunlana, 1989; Skitmore *et al*, 1990). Similarly the Floor Area and number of Storeys Above Ground may be also considered as measures of 'size'.

The correlation analyses of the Singapore data indicated that a number of variables were significantly correlated with contract sum and so this was chosen as a starting point the analysis.

The other 'size' variables, along with Price Intensity, that were significantly correlated with contract sum are (the correlation with contract sum variable is shown in parenthesis):

1 Price Intensity (r = 0.397)
2 Floor Area (r = 0.756)
3 Number of Storeys Above Ground (r = 0.848)
4 Contract Period (r = 0.567)
5 Number of Drawings (r = 0.359)
6 Number of Priced Items (r = 0.323)

That Price Intensity is significantly correlated with the Contract Sum indicates that 'expensive' buildings, on a Price Intensity ($/m2) basis, also tend to be expensive in terms of total cost.

The dependent and independent variables used are described in detail in Gunner (1997). Unless otherwise mentioned, 'Gross Ratio' was used as the dependent variable.

Testing for the Regression Assumptions

The residuals from all the regression analyses were tested to ensure compliance with the basic assumptions inherent in linear regression, namely:

1There is no multicollinearity among the independent variables.
2There is no auto correlation in the residuals.
3The residuals are normally distributed.
4The conditional variance of the residuals is homoscedastic.

These tests were applied in a manner equally as stringent as that facing the PI theory. Wherever possible, the most powerful statistical tests were applied strictly to each and every assumption.

The residuals were tested for auto correlation using the Durbin Watson d statistic, for normality in their distribution by using the Kolmogorov-Smirnov test, for multicollinearity by the Eigenvalue Test (see Gujarati, 1988:299) and for homoscedasticity of variances by using the Lagrange Multiplier (see Maddala, 1992:233).

Results

Table 1 summarises the results of the regression analyses along with the Beta values to allow comparison of the relative contribution of each independent variable, the t values and tests on regression assumptions.

None of the analyses failed to pass the auto correlation, distribution and multicollinearity tests. Of the eight analyses failing to satisfy the homoscedasticity assumption, seven produced chi-square values very slightly above the critical value of 3.841. Of these, five passed Levene's test for homoscedasticity leaving only two, Contract Work Type and Contract Period, as marginal. Based on a 5% confidence level and with twenty four independent variables it was expected that at least one of these marginal cases would be spurious. In view of this, and to avoid making

unnecessary Type II errors, all the analyses except that involving Preliminaries % were taken to have passed to assumptions tests.

These results show that, in twenty two out of the twenty four analyses, Price Intensity was significant while the added variable was not significant. Of the two exceptions, one involved a 'near' result for Price Intensity (p=0.072) and the other failed to meet the homoscedasticity assumption.

The Box and Cox methodology was then used to transform the dependent (Gross Ratio) variable by various powers at 0.50 intervals through a range of ■ -2.00 to +2.00. Square root, reciprocal and reciprocal square root deflators were also applied to the dependent variable and several independent variables. None of the transformations or deflators produced any evidence of the existence of a different underlying variable to Price Intensity.

Further tests on the PI model

The model

From the above, the Price Intensity variable emerged as the only likely candidate as an underlying factor. The plot in Fig 1 provides a visual rendition of the data and model, the outer lines delineating the 5% confidence limits.

The Price Intensity model (Gross Ratio) is

$R = 1.152 - 7.2(10\text{-}5)I$

whereR = Gross Ratio (price forecast ÷ awarded contract sum)
I = Price Intensity (rebased awarded contract sum ÷ floor area)

The model provides a good fit ($F=5.24$, $p<0.025$) and Price Intensity is highly significant ($t=24.80$, $p<0.000$) but has a high standard error of estimate (0.20) and explains only a relatively small part of the overall variation ($r^2=0.068$, adjusted $r^2=0.056$). The small value of the regression coefficient is mostly a reflection of the relatively small values of the Gross Ratio, with a mean value of 1.06 and a range between 0.63 and 2.40 (lower quartile 0.99 upper quartile 1.10), and the large values of the Price Intensity variable, with a mean of 1 279 and a range between 21 and 3 525 (lower quartile 790 upper quartile 1 672). It should also be noted that only 73 cases, out of the full sample 181 cases), were used to build the model observations due to data limitations caused by the absence of a price index for the older cases.

A further regression was run with the Net Ratio as the dependent variable. This resulted in a similar equation but with the percentage explained still rather low at 6%.

Outliers

The histogram of the residuals was inspected for any visual indication of abnormalities that might have not been detected by the Kolmogorov-Smirnov test. This indicated a trivially slight

peaked distribution. The residuals were also plotted against each of the independent variables as a visual check against the Lagrange Multiplier test and no systematic features were observed to indicate undue heteroscedasticity. The plots did, however, indicate three outliers in excess of ±2.5 standard deviations from the mean. Two of these were demolition contracts and one a refurbishment contract. The possibility that, due to their specialised nature, these contracts may be more difficult to forecast was ruled out on the grounds that no outliers occurred with the other seven demolition contracts and thirteen refurbishment contracts included in the data. An OLS regression was run on the data excluding the three observations identified to establish whether these points were of significant influence on the model. The regression summary of the selected model without outliers (seventy observations) was then compared with that for the full model (seventy three observations). The results showed that both models are significant and that in both cases the Price Intensity variable remains a significant factor in the equation. Generally the ■selected■ model is a better fit having a higher adjusted r^2 and smaller standard error. However the Beta values of -0.262 and - 0.300 revealed a very small difference in the relative contribution to the prediction of the Gross Ratio. The ■ coefficients were both negative, indicating that the slope of the regression line is consistent. The actual values of the coefficients were -0.000072 for the full model and -0.000041 for the selected model, indicating a minimal influence of these three observations on the regression.

Missing variables

As the model includes only one significant variable, this raises the question of whether a relevant variable has been omitted from the model. In the absence of any alternative theories or possibilities of collecting additional data, it was only possible to look for a relevant omitted variable in the available data. Gujarati (1988:404) and Maddala (1992:63) detailed statistical techniques for doing this and an exhaustive approach was adopted to ensure that no such specification error had occurred. This involved leaving one independent variable in the model along with Price Intensity and then adding another independent variable to see whether the third variable made any significant difference to the equation. If Price Intensity is the only significant variable then no other added variable should be significant of itself. A total of 506 regressions were conducted during this analysis and of those 146 were found to meet the assumptions of regression analysis. Of these 146 analyses, 115 (79%) showed Price Intensity to be the only significant variable in the equation. Of the remaining 31 analyses, the Price Intensity p value was between 0.051 and 0.060 in 25 cases and between 0.060 and 0.070 in 6 cases.

Functional Form

A number of different forms were fitted to the PI model in order to establish whether a better fit may be obtained. The criterion used to judge the best goodness of fit was the adjusted r^2. Apart from the more general functional forms of log, reciprocal, square root etc., polynomial functional forms were fitted to the data using OLS regression. None of the alternative functional forms was able to provide a higher adjusted r^2 than the linear model.

Post sample predictive power

The model was applied to six new cases that became available after the model was constructed. The results in Table 2 show that the predictions were greater than observed values of all the post sample observations. Four of the six observations were also negatively biased, ie. with a Gross Ratio below 1.00. Overall bias in both data sets is positive but the proportion of observations with a negative bias in the within sample data set is 30%. On this basis it is possible that the small number of post sample observations are not entirely representative of the population and may not be facilitating reasonable comparisons.

Theoretical Consistency

The model shows that the sign of the coefficient is negative and crosses the Price Intensity axis (Fig 1) at the approximate half-way point. The practical outcome of this is, as predicted by PI theory, that less expensive contracts tend to be over-estimated to a greater degree than more expensive contracts. This negative trend corresponds with results of previous research in regard to the 'size' variables of Contract Sum and Floor Area (eg. Harvey, 1979; Morrison and Stevens, 1980; Flanagan and Norman, 1983; Morrison, 1984; Skitmore, 1988) which showed that, as the value of the independent variable increased, bias in the price forecast decreased. However, the Price Intensity variable, though correlated, is not a measure of 'size' in itself.

Of more relevance in assessing theoretical consistency would be other findings in relation to the Price Intensity variable. The only instance of this is in Skitmore *et al*'s (1990) experimental work with early stage forecasters. Although their research was essentially aimed at identifying the bias-affecting characteristics of forecasters, a few project related variables, including Price Intensity, were also examined. Encouragingly, their analysis also found a significant, negative, regression coefficient for Price Intensity. However, with only a small number of contracts (fifteen) available for analysis, they were reluctant to conclude that this result was anything more than "indicative".

GENERALISATION OF PI THEORY

Compliance with previous findings

The literature review revealed that a considerable number of independent variables had been found, or speculated, to be of significant effect on the building contract price forecast errors. Gunner (1997) tested the significance on many of these in a series of bivariate analyses conducted on a sample of Singapore data, said to be "representative of the industry at large" world-wide. The result of this was to show that the results of Gunner's and all the comparable larger studies in this field are in general agreement with each other. Table 3 lists all the variables involved in terms of both bias and consistency. The analyses described in this paper indicated that, of these, all except three variables (the results of which are inconclusive due to failure to meet the multiple regression assumptions) were confounded with Price Intensity, *ie.* although significant in bivariate analysis, they ceased to be significant once the effects of Price Intensity was removed.

By extension, this finding could equally apply to previous work had those researchers sought out

confounding effects with the Price Intensity variable. It has to be concluded therefore that PI theory is not disconfirmed, as the lack of investigation into confounding effects by previous researchers has resulted in no counter evidence being available.

CONCLUSIONS

This paper introduced a new theory of building contract price forecasting bias based primarily upon the work of Tversky and Kahneman. They investigated the heuristics and biases which occur when making predictions in an uncertain environment. Their findings, together with the common practice use basing forecasts on unit floor area, provides the basis of PI theory.

At a more pragmatic level, previous work using bivariate analysis was shown to support the results of this work, where those findings was based upon relatively robust analyses. Tests of the theory did not reveal sufficient evidence to reject the concept that, after partialling out the effect of all other independent variables, Price Intensity is the underlying factor associated with systematic bias in building contract price forecasts.

The results of this work were generalised beyond the source of data for this study to suggest that the PI theory is representative of the industry at large. It was also noted that PI theory should also apply equally at any stage of the design development process when contract price forecasts are made, from early stage forecasts to those at the pre-bid stage.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the time, help and guidance of Winston Hauw, Lai Meng Seng of Rider Hunt Levett and Bailey, Singapore, and Martin Betts and David Skinner of the University
of Salford, UK.

REFERENCES

Beeston, D.T., 1974, *One statistician's view of estimating*, *Cost Study F3*, London: Building Cost Information Service.

Cheong, P.F., 1991, Accuracy in design stage cost estimating, MSc dissertation: National University of Singapore.

Flanagan, R., 1980, Tender price and time prediction for construction works, PhD thesis, University of Aston in Birmingham.

Flanagan, R., Norman, G., 1983, The accuracy and monitoring of quantity surveyors' price forecasts in building work, *Construction Management and Economics*, **1**(2) 157-80.

Fortune, C., Lees, M., 1996, The relative performance of new and traditional cost models in strategic advice for clients, *RICS Research Paper Series*, **2**(2), The Royal Institution of Chartered

Surveyors, 12 Great George Street, London SW1P 3AD, ISBN 0 85406 767 1.

Gujarati, D.N., 1988, *Basic econometrics*, 2nd ed, McGraw Hill.

Gunner, 1997, A model of building price forecasting accuracy, PhD thesis, Department of Surveying, University of Salford.

Gunner, J., Betts, M., 1990, Price forecasting performance by design team consultants in the pacific rim, *Value in Building Economics and Construction Management CIB W-55/65 Symposium Sydney*, 3, 302-12.

Harvey, J.R., 1979, Competitive bidding on Canadian public construction contracts: stochastic analysis for optimisation, PhD thesis, School of Business Administration, University of Western Ontario.

Hogarth, R.M., 1987, *Judgement and Choice*, 2nd ed, Wiley.

Jupp Mansfield & Partners, 1981, Reliability of detailed cost data for estimating during detailed design, (unpublished), Oct.

Lau H.M., 1991, Public sector estimating accuracy, MSc dissertation, National University of Singapore.

Maddala, G.S., 1992, *Introduction to economics*, 2nd ed, Simon and Schuster.

Morrison, N., 1984, The accuracy of quantity surveyors' cost estimating, *Construction Management and Economics*, **2**(1) 57-75.

Morrison, N., Stevens, S., 1980, *Construction cost data base*, 2nd annual report of research project by Department of Construction Management, University of Reading, for Property Services Agency, Directorate of Quantity Surveying Services, DOE.

Ogunlana, S., 1989, Accuracy in design cost estimating, PhD thesis, Loughborough University of Technology.

Raftery, J., 1996, Quasi-rational behaviour in the property and construction market, *Proceedings*, 7th Int Symp, The International Council for Building Research Studies and Documentation CIB W-55, 4-7 Sep, M Katavic (ed), Faculty of Civil Engineering, University of Zagreb, Kaciceva, Croatia, ISBN 953 96245 2 5, 469-85.

Skitmore, R.M., 1985, *The influence of professional expertise in construction price forecasts*, Salford: The University of Salford, ISBN 0 901025 09 7.

Skitmore, R.M., 1988, Factors affecting accuracy of engineers Estimates, *Cost Engineering*, **30**(10), 16-23.

Skitmore, R.M., Stradling, S.G., Tuohy, A.P., Mkwezalamba, H., 1990, *The accuracy of construction price forecasts: a study of quantity surveyors' performance in early stage*

estimating, Salford: The University of Salford, ISBN 0 901025 12 7.

Thng, 1989, Estimating accuracy at public sector - housing development board, MSc dissertation, National University of Singapore.

Tversky, A., Kahneman, D., 1982, Judgement under uncertainty: heuristics and biases, in *Judgement under Uncertainty: Heuristics and Biases*, D Kahneman, P Slovic and A Tversky (eds), CUP, 3-20.

Wilson, O.D., Sharpe, K., Kenley, R., 1987, Estimates given and tenders received, *Construction Management and Economics* **5**(3).